(12) UK Patent Application (19) GB (11) 2 242 848 (13) A

(43) Date of A publication 16.10.1991

(21) Application No 9008466.6

(22) Date of filing 12.04.1990

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(51) INT CL[5]
B23K 20/12

(52) UK CL (Edition K)
B3R RK R15

(56) Documents cited
GB 2222378 A WO 88/07907 A WO 87/04957 A

(58) Field of search
UK CL (Edition K) B3R
INT CL[5] B23K

(54) **Depositing coating on materials**

(57) In a method of forming a surface of a first material on a second material by bringing a rotating body of the first material into contact with the surface of the second material, the first material is a metal matrix composite containing particularly alumina or silicon carbide.

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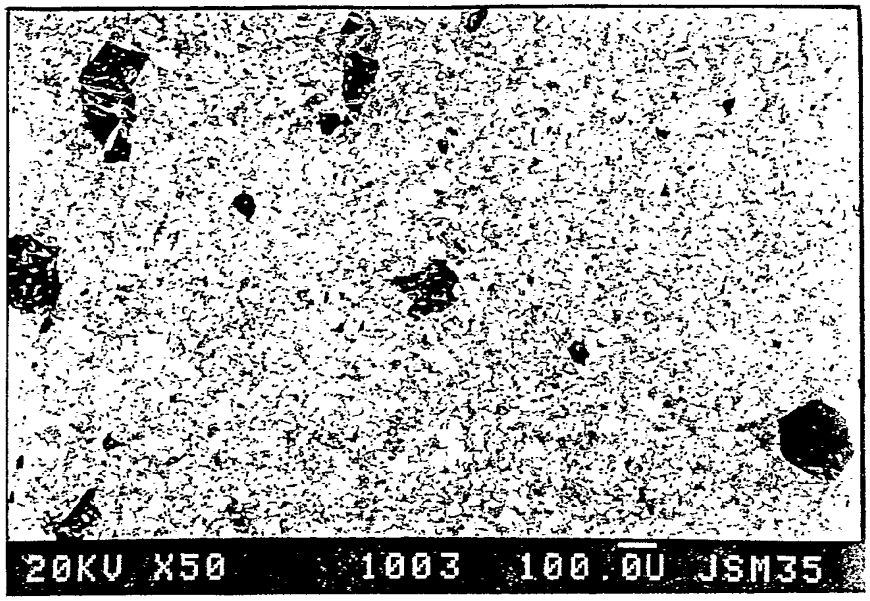

FIG.1

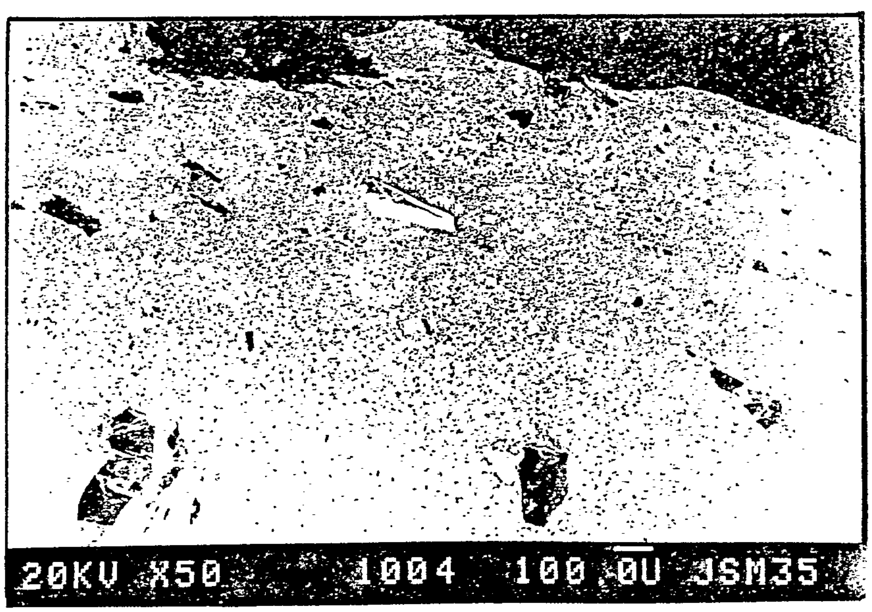

FIG.2

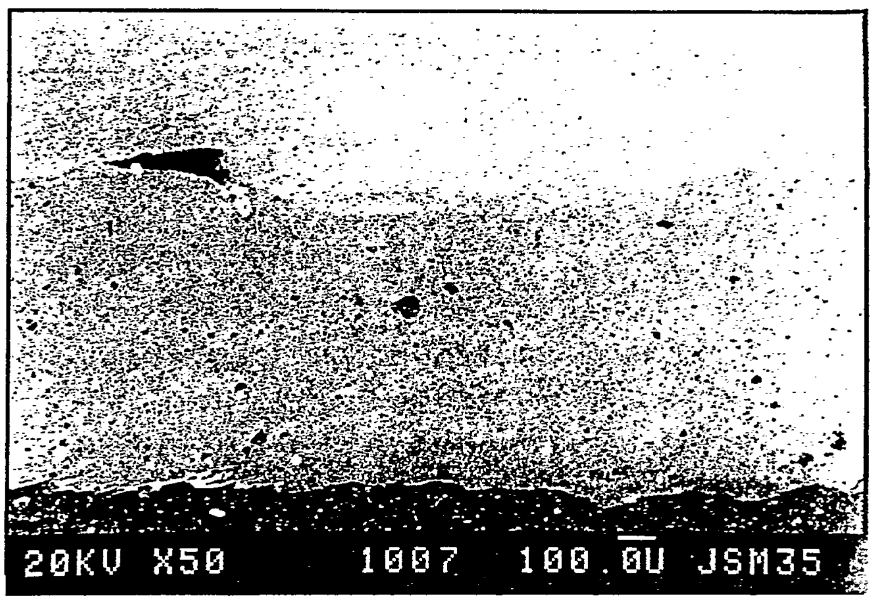

FIG. 3

DEPOSITING COATING ON MATERIALS

The present invention relates to a method for depositing a coating on a material.

A method for applying a relatively thick hard facing along an edge of a substrate by relative translational movement is disclosed in our International Publication No. WO 87/04957. A non-translational movement for forming relatively thick cylindrical or annular deposits is disclosed in our International Publication No. WO 88/07907. These two publications disclose use of the phenomenon of interface movement to build relatively thick coatings of a relatively hard material such as stellite or high speed tool steel on a relatively soft substrate such as plain carbon steel. The deposit formed is a homogeneous layer of the relatively hard material and is more than 0.2 mm thick.

The phenomenon of interface movement had been disclosed by K. Fukakusa et al "Travelling Phenomena of Rotational Plane during Friction Welding", Research Reports of Fukui Technical College, Natural Science and Engineering, No. 18 December 1984. However, that phenomenon had been disclosed by Fukakusa in the

context of friction welding where it was undesirable and lead to uncertainty in the length of the weld zone.

In one aspect this invention relates to a method of forming a surface of a first material on a second material by bringing a rotating body of the first material into contact with the surface of the second material, characterised in that the first material is a metal matrix composite.

The term "metal matrix composite" is defined to mean a material consisting predominantly of a metal matrix in which there are particles or fibres of a non-metallic material, for example silicon carbide fibres and particles and particles of alumina. Typical such materials include titanium reinforced with silicon carbide, nickel reinforced with silicon carbide, aluminium reinforced with silicon carbide or alumina, steel (ranging from plain tool steels to high speed tool steels) reinforced with silicon carbide or alumina, and stainless steel reinforced with alumina. The material of the rotatory body is advantageously formed by a spray deposition process in which metal from a tundish is atomised with an inert gas and a ceramic material in powdered form is admixed with the

atomised metal, the mixed materials being sprayed onto a substrate to form a deposited material which is converted into a rod. Such a spray deposition process has been developed by OSPREY Metals Limited of Neath, UK. Rods of metal matrix composite materials made by conventional casting methods can also be used.

Deposits of cylindrical or annular form may be formed by a so-called "touchdown" method in which there is no translational movement between the rotating body and the substrate, but the substrate is positively cooled, for example by water or a conductive liquid to bring about the interface movement required to form a thick deposit (see WO 88/07907). In order to form a deposit that can be further shaped by metal removal processes such as grinding, it must be at least 0.2 mm thick, and the interface movement phenomenon referred to above is required to bring about the formation of a deposit of sufficient thickness. In order to do this, the substrate is positively cooled, preferably by water or another conductive liquid, and in order to build up a deposit of a significant or semi-infinite height, the level of the water or other conductive liquid is adjusted continuously during the deposition process so that the level follows the gradually

forming deposit and the required cooling of the interface is maintained.

In this non-translational process, the substrate may conveniently be a rod or bar for the manufacture of an edge tool such as a screwdriver or chisel, or for the manufacture of a twist drill or other similar tool, or for the manufacture of a component including a near-net shape component.

The substrate material may be plain carbon steel or aluminium. The coating may be detached from the substrate and recovered. The rotatory body may be pre-formed with a diameter that varies along its length so as to give rise to a deposited coating of predetermined profile.

In a second form, a strip-like coating is formed by relative translational movement between the rotatory body and the substrate (see WO 87/04957). The coating may be deposited under axially symmetric conditions on a plain surface of the body, or in a recessed groove in the middle of the body, or it may be deposited under asymmetric conditions e.g. in a recess along the edge of the body. Again, to be practically useful, the coating should be thick enough to be

subjected to finishing by a metal removal process, and for this purpose it should be at least 0.2 mm thick and preferably somewhat thicker than this. Again, the interface movement must be brought about in order to give rise to a coating of sufficient thickness, and the speed of rotation of the body, the pressure applied at the interface between the body and the surface and the speed of relative movement are such that a shear layer at which heat is being generated moves away from the surface in the direction of the rotatory body, so that on removing the rotatory body from contact with the surface, the second material is found to be surfaced with a relatively thick layer of the first material.

The coating of metal matrix composite may also be applied to a stack of blade laminae clamped together as described in our U.K. patent application No. 8820448.2 (Publication No.2222378A), after which the stack can be separated into individual blades. The coating could, for example, have particles of alumina in high speed steel or stainless steel.

The translational movement may be linear so as to give rise to a linear coating, or non-linear translational movement is possible to provide coatings of circular,

part-circular, annular or angular shape when viewed in plan, the substrate being planar. In a variant, the substrate may have a cylindrical side surface (it may be a solid rod or a thick-walled tube) and the deposited coating material may form an annulus or spiral thereon. In a variant of the latter process, the substrate may be relatively hard and the rotating body may be relatively soft. The coating may be built up in a single pass or in repeated passes, with the material deposited at each pass being a homogeneous layer at least 0.2 mm thick. The materials deposited in the various passes may differ so as to give rise to a multi-layer or sandwich structure. A further feature of the invention is that the deposited material may be detached and recovered, and in this aspect of the invention the deposited material need not be a metal matrix composite.

The deposited material may then be taken to the final shape e.g. by a metal removal process, before detachment or after detachment so that it may be subjected to grinding or other metal removal processes at its major faces or end and formed into any desired shape e.g. a square bar or into a rod.

To facilitate detachment, a brittle layer may be

caused to form either simultaneously with the formation of the deposited coating or on a subsequent heat treatment process. The possibility of separation may be brought about either by selecting the combination of materials used, or by selecting the process conditions or both. For deposition of a metal matrix reinforced aluminium body onto an aluminium substrate and subsequent spontaneous separation of the deposited coating, an aluminium substrate is used and the process conditions are selected so as to bring about the spontaneous separation. As an example of a combination of materials in which there is a hard brittle intermediate phase at the interface that grows by subsequent heat treatment, there may be mentioned the combination of a rotating aluminium body on an iron substrate. In this case, at the deposition interface, very hard and brittle phases of the composition $Fe_x Al_y$ grow and the deposit becomes detached automatically. Other such combinations of materials include aluminium on copper and zinc or tin on iron. A further possibility is to use a substrate that has high hardenability so that a thin layer of hard brittle material develops in the substrate at the time of deposition of the coating. For example, if the substrate is a low alloy steel, martensite

develops at the heat affected zone of the substrate adjacent the interface with the deposit, and that martensitic material is in the form of a thin brittle layer that facilitates detachment of the deposited material.

In the deposition of metal matrix composite materials, a particular feature of the process is the extent to which particles of ceramic in the metal matrix become broken up and scattered in the resultant coating. Figure 1 is a micrograph of a rotatory body of metal reinforced composite material, in this case a low alloy steel reinforced with particles of alumina of nominal size 230 micrometres occupying about 5 to 10% by volume, 90% of the particles having sizes within the range of 180-350 micrometres. In Figure 2 there is shown the lower region of a rod which has been used for forming a coating by "touchdown". In the lower part of the Figure the large particles of alumina appear, and in the upper part of the Figure adjacent where the friction interface was formed it will be noted that the particles are substantially broken up into smaller sizes. This reduction in particle size of the alumina is by mechanical break-up of the individual particles unlike the carbides in high speed steel which are broken up by mechanical action and

also partly by solution of the particles and recrystallization thereof on cooling. Figure 3 is a micrograph of a section of the coating which has been deposited on a low carbon steel substrate and in which there is relatively small size alumina particles, the size range being typically in the range of from 10 to 50 microns or less. Surprisingly good adhesion between the matrix metal and the alumina ceramic particles is noted, and there is no evidence of delamination resulting in voids in the vicinity of the individual particles. The relatively small particle size of ceramic material dispersed in the metal is difficult to obtain by the conventional spray method because it is difficult to mix such fine particles of the ceramic with the powdered metal and to obtain such a uniform distribution of the ceramic particles in the resultant coating or finished material. It will be observed in Figure 3 that the matrix metal is of too fine a microstructure to be perceived in the electron micrograph, the microstructure being much finer than that in the original rod in which the microstructure is clearly perceptible, and having been refined as a result of the hot forging action which is inherent in the rotatory friction surfacing process. The deposited material is in a hardened state, and will typically be

tempered back by a conventional tempering heat treatment.

The invention will now be further described with reference to the following examples.

Example 1

A mild steel plate 6.3 mm thick was coated with a circular deposit of a steel based metal matrix composite material without relative lateral movement and with cooling of the steel plate by thermal contact with a water-cooled copper plate generally as disclosed in International Application No WO 88/07907. The rotating rod used to form the coating was of 10 mm diameter and was an Osprey steel/alumina metal matrix composite based on steel containing 0.73% carbon, 0.22% silicon, 0.53% manganese and a 0.09% chromium, all by weight the balance being iron. Dispursed through the iron were particles of alumina in the range of 5 to 10% by volume, the alumina being in the form of particles of average size to 130 microns with 90% of the particles being in the range of 180 to 350 microns. The deposit was formed by rotating the rod in contact with the steel substrate at a speed of 1500 rpm under a force of 6KN for a period of ten seconds.

The deposition conditions were selected so that the friction interface at which heat was being generated moved away from the surface of the steel plate along the direction of the rotating rod so as to become spaced from the mild steel plate, and the steel plate was positively cooled in order to bring about this interface movement. The resulting deposit of metal matrix composite material in a hardened state had a height of 1.6 mm, which could be readily increased as desired by additional water cooling.

Example 2

An aluminium alloy plate of thickness 6 mm was coated with heat treatable aluminium alloy (HE 30) in the form of a rod of diameter 25.4 mm. The coating was carried out with relative translational or lateral movement as disclosed in International patent application No Wo 87/04957 and using apparatus generally as described in that specification. The coating was applied to the face of the sheet rather than in an edge recess as in WO 87/04957 by rotating the rod at 1250 rpm with an applied force of 8 KN and with a speed of lateral movement of a table of the coating machine to which a substrate was clamped of 5

mm per second. The force and rotational speed and the rate of relative translational movement had been selected so that movement of the friction interface away from the aluminium substrate took place, and a strip of HE 30 aluminium alloy was coated onto the substrate which was 6 mm thick and 25 mm wide. After coating had been completed the coated strip which was only loosely adhered to the substrate was detached and prised off readily as a single solid piece, after which it was ready for final shaping e.g. by milling or other metal removal processes.

It will be understood that the procedure described in this example is equally applicable to the deposition of a coating in an edge recess region of a substrate.

Example 3

A detachable strip of nickel based coating material was formed on a stainless steel substrate using the same general conditions as described in example 2. The substrate was a sheet of 316 stainless steel 4 mm thick and the coating material was Wall Colmonoy Alloy C5 containing 11.5% chromium, 4.25% iron, 3.75%

silicon, 2.5% boron and 0.65% carbon all by weight, the balance being nickel. The coating material was in the form of a rod 6.4 mm in diameter. The coating was applied at a rotational speed of 810 rpm using a force of 5.6 KN and a table speed of 2.5 mm per sec. Under the selected coating conditions interface movement away from the stainless steel substrate occurred and the substrate was coated with a strip of the C5 alloy 1.4 mm thick and 6 mm wide. After coating was complete the coating material which was weakly adhered could readily be prised off. It was free from major defects and ready for grinding, milling or other finishing operations.

Example 4

Using the same machine as in example 2 .a detachable strip coating of Inco 625 alloy material was formed on a low alloy hardenable steel substrate (EN19T) 2.5 mm thick. The coating was applied from a rod of the Inco 625 alloy 12.5 mm in diameter at a rotational speed of 700 rpm, a force of 17 KN and a table speed of 4 mm per second. The coating conditions were selected so that the friction interface which heat was being generated moved away from the surface of the substrate

and there was produced on the substrate a strip of coating material 1.4 mm thick and of width 12.2 mm.

The deposition conditions were such that Martensite was formed in the heat affected zone of the substrate, and as a result of the formation of a brittle Martensite layer between the coating and the remainder of the substrate the coating could be detached by being prised off with a screwdriver as a strip ready for subsequent grinding, milling or other finishing operations.

CLAIMS:

1. A method of forming a surface of a first material on a second material by bringing a rotating body of the first material into contact with the surface of the second material, characterised in that the first material is a metal matrix composite.

2. A method according to claim 1, wherein the metal of the matrix is titanium and the reinforcing material is silicon carbide.

3. A method according to claim 1, wherein the metal of the matrix is nickel and the reinforcing material is silicon carbide.

4. A method according to claim 1, wherein the matrix is of aluminium and the reinforcing material is silicon carbide.

5. A method according to claim 1, wherein the material of the matrix is steel and the reinforcing material is alumina or silicon carbide.

6. A method according to any preceding claim wherein the material of the rotating body has been made by a spray deposition process.

7. A method according to any preceding claim, wherein the deposition is carried out with relative movement in one plane only and the second material adjacent to the contact surface is positively cooled, the speed of rotation of the body and the pressure applied being adjusted having regard to the cooling conditions so that a sheer layer or friction interface at which heat is being generated moves away from the surface in the direction of a rod or bar of the relatively hard material so that on removing the rod or bar from contact with this surface the second material is found to be surfaced with the first material.

8. A method according to claim 7, wherein the positive cooling is by contact with water or another conductive liquid.

9. A method according to claim 8, wherein the position of the surface of the cooling water is adjusted having regard to the position at which friction is occurring so as to maintain movement of the frictional interface.

10. A method according to any preceding claim, wherein the depth of the deposit is at least 0.2mm.

11. A method according to any preceding claim, wherein the depth of the deposit is at least 0.4mm.

12. A method according to any preceding claim, wherein the substrate is a rod or bar.

13. A method according to any preceding claim, wherein the substrate is of mild steel or aluminium.

14. A method according to any of claims 6 to 13 comprising the further step of detaching the deposited coating.

15. A method according to any preceding claim, wherein the diameter of the rotating body varies along its length to provide a deposited coating having a predetermined profile corresponding to the shape in the rotating body.

16. A method according to any of claims 1 to 6, wherein there is relative translational movement between the rotatory body and the substrate.

17. A method according to claim 16, in which the material of the rotatory body is deposited on the substrate under axially symmetric conditions.

18. A method according to claim 16, wherein the material of the rotatory body is deposited on the substrate under axially asymmetric conditions.

19. A method according to claim 17, wherein the material of the rotatory body is deposited on a plane surface region of the substrate.

20. A method according to claim 17, wherein the material of the rotatory body is deposited in a recessed region of the substrate.

21. A method according to claim 18, wherein the material of the rotatory body is deposited in a recessed edge region of the substrate.

22. A method according to any preceding claim, wherein the pressure, rate of rotation and rate of relative translation or movement between the rotatory body and the substrate is such that the friction interface rises from a position in contact with the substrate to a position along the rotatory body spaced

a small distance from the substrate so as to deposit on the substrate a homogeneous layer of material more than 0.2mm thick.

23. A method according to any of claims 16 to 22, wherein the relative translational movement follows a non-linear path.

24. A method according to claim 23, wherein the path is an annulus, a spiral, part of a circle, or is angular.

25. A method according to claim 16, 17, 22 or 23, wherein the substrate has a cylindrical side surface on which the relatively hard material is deposited in an annulus or along a spiral.

26. A modification of the method of claim 25, in which the rotatory body is relatively soft and the substrate is relatively hard.

27. A method according to any of claims 16 to 26, in which the deposited material is built up in repeated passes, each pass depositing a homogeneous layer of the material of the rotatory body at least 0.2mm thick.

28. A method according to any of claims 16 to 27 comprising the steps of detaching the deposited material from the substrate or allowing it to become detached, and recovering the deposited material.

29. A method according to claim 28 comprising the further step of shaping the deposited material before it has become detached.

30. A method according to claim 28, wherein the deposited material is shaped after it has become detached.

31. A method according to claim 28, 29 or 30, in which the materials of the rotatory body and of the substrate are selected so that a brittle interlayer between the deposited material and the substrate is formed either at the time of deposition or on subsequent heat treatment.

32. A method according to claim 31, in which the brittle layer forms by inter-diffusion caused by heat treatment, which brings about growth of a brittle phase at the interlayer between the substrate and the coating.

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